



(11) **EP 3 187 251 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**05.07.2017 Bulletin 2017/27**

(51) Int Cl.:  
**B01D 71/82** <sup>(2006.01)</sup> **C08G 61/08** <sup>(2006.01)</sup>  
**C08J 5/22** <sup>(2006.01)</sup> **H01M 8/083** <sup>(2016.01)</sup>  
**H01M 8/1023** <sup>(2016.01)</sup>

(21) Application number: **16172017.2**

(22) Date of filing: **30.05.2016**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**  
Designated Validation States:  
**MA MD**

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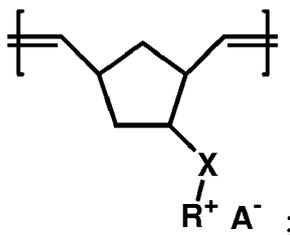
(30) Priority: **28.12.2015 TW 104143989**

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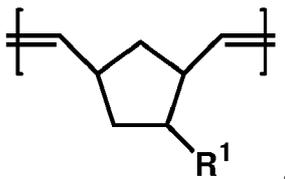
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(54) **POLYMER AND METHOD FOR PREPARING THE SAME**

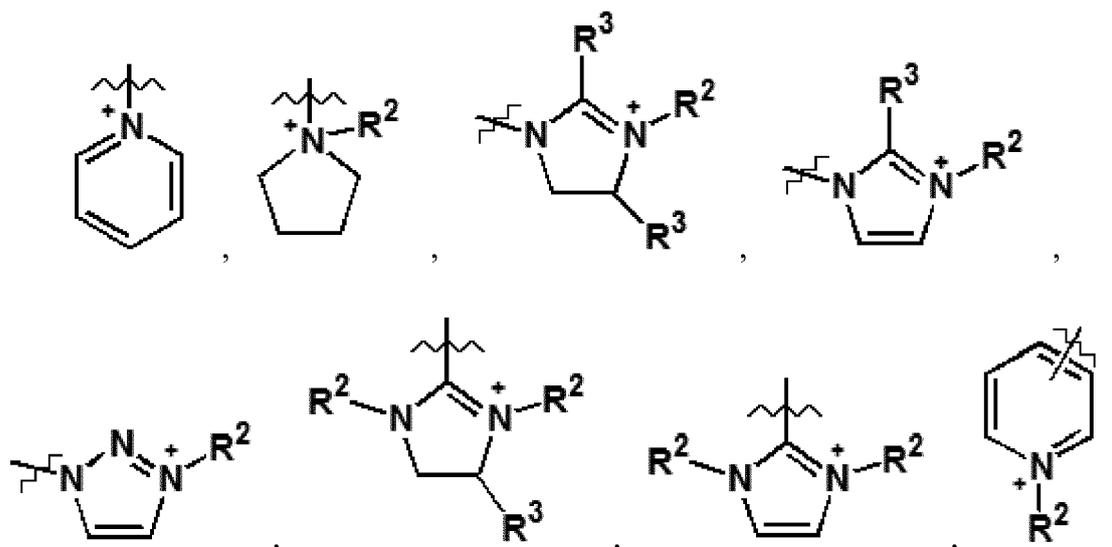
(57) A polymer and a method for preparing the same are provided. The polymer includes a first repeat unit and a second repeat unit. In particular, the first repeat unit is



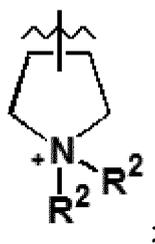
and, the second repeat unit is



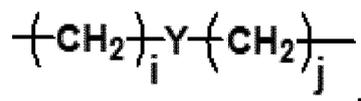
wherein R<sup>+</sup> is



or



A<sup>-</sup> is F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X is



i and j are independently 0, or an integer from 1 to 4; Y is -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> is independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> are hydrogen, or independently C<sub>1-8</sub> alkyl group.

Description

TECHNICAL FIELD

5 [0001] The technical field relates to a polymer and a method for preparing the same.

BACKGROUND

10 [0002] Ion exchange membranes are widely used in electrodialysis purification, fuel cells, electroplating, and the food industry.

[0003] An ion exchange membrane includes a polymer material having negatively charged groups or positively charged groups serving as the film body, and migratable cations or anions under electrical or chemical potential. A cation exchange membrane has negatively charged groups fixed on the polymer and migratable cations. Identically, an anion exchange membrane has positively charged groups fixed on the polymer and migratable cations. In general, the characteristics of the ion exchange membrane are determined by the number, type, and distribution of the fixed charged group. Anion exchange membranes made of conventional polymer material are not suitable for use in an ion exchange membrane fuel cell, due to the poor solubility, mechanical strength, and solvent selectivity of the conventional polymer material.

SUMMARY

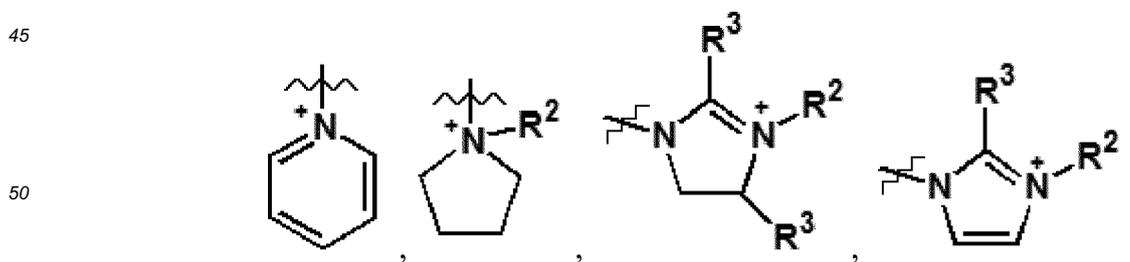
20 [0004] According to an embodiment of the disclosure, the disclosure provides a polymer including a first repeat unit and a second repeat unit, wherein the first repeat unit can be



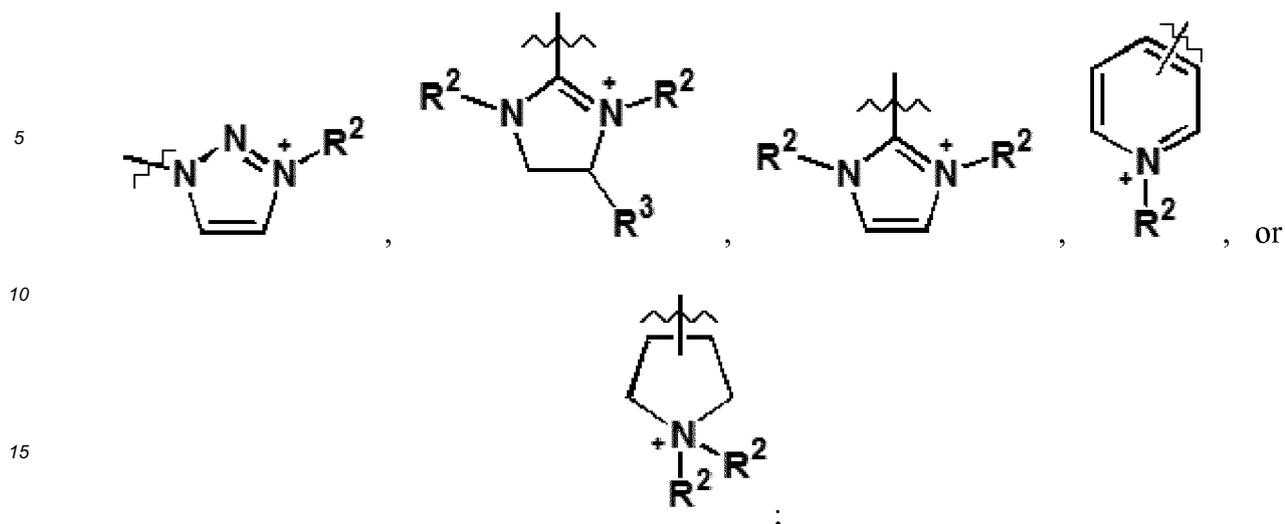
the second repeat unit can be



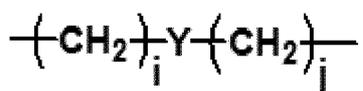
wherein R+ can be



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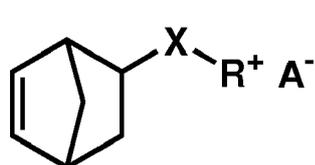


20 A<sup>-</sup> can be F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X can be

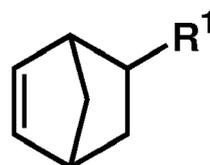


i and j can be independently 0, or an integer from 1 to 6, Y can be -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> can be independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> can be independently hydrogen, or C<sub>1-8</sub> alkyl group.

30 **[0005]** According to other embodiments of the disclosure, the disclosure provides a method for preparing the aforementioned polymer. The method includes subjecting a composition to a polymerization. In particular, the composition includes a first monomer having a structure of Formula (I) and a second monomer having a structure of Formula (II)

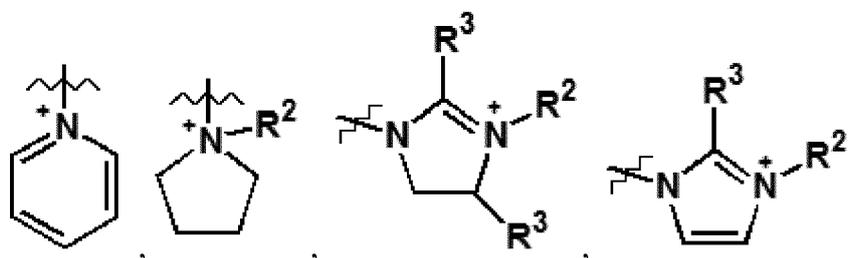


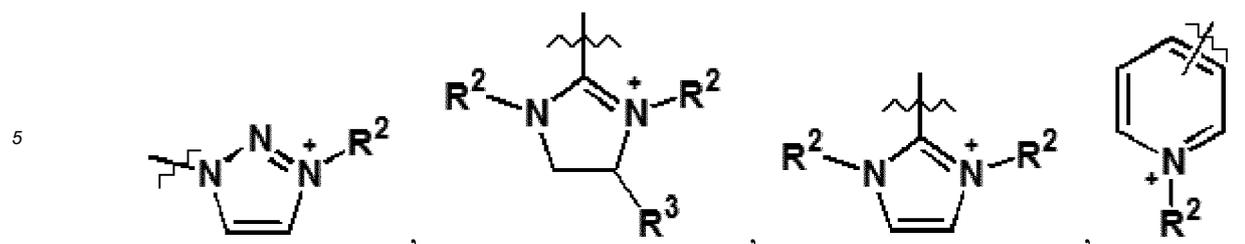
Formula (I)



Formula (II)

40 , wherein R<sup>+</sup> can be





10 or



$A^-$  can be  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $OH^-$ ,  $HCO_3^-$ ,  $HSO_4^-$ ,  $SbF_6^-$ ,  $BF_4^-$ ,  $H_2PO_4^-$ ,  $H_2PO_3^-$ , or  $H_2PO_2^-$ ; X can be



30 i and j can be independently 0, or an integer from 1 to 6, Y can be -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> can be independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> can be independently hydrogen, or C<sub>1-8</sub> alkyl group.

**[0006]** A detailed description is given in the following embodiments with reference to the accompanying drawings.

### DETAILED DESCRIPTION

35 **[0007]** In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details.

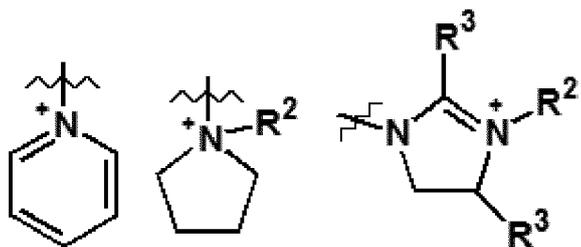
40 **[0008]** The disclosure provides a polymer and a method for preparing the same. The polymer of the disclosure can be a polymer with a cationic group (such as a highly stable cyclic conjugated cationic group) and non-ionic group (such as long-chain group). In the chemical structure design, in order to enhance the electrical conductivity of the polymer, the polymer of the disclosure has a repeat unit with a cationic group. In addition, the polymer of the disclosure has a repeat unit with a non-ionic group, in order to prevent the solubility of the polymer having cationic groups from decreasing when dissolving in a solvent. According to embodiments of the disclosure, besides the high solubility, the polymer of the disclosure exhibits improved mechanical strength and increased solvent selectivity.

45 **[0009]** According to an embodiment of the disclosure, the polymer of the disclosure includes a first repeat unit and a second repeat unit. The first repeat unit can be

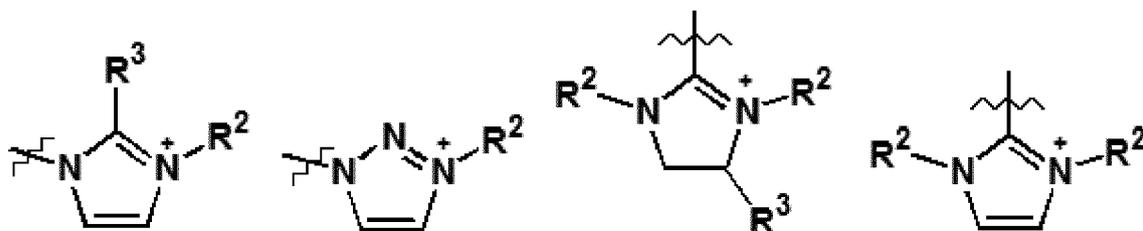


wherein R<sup>+</sup> can be

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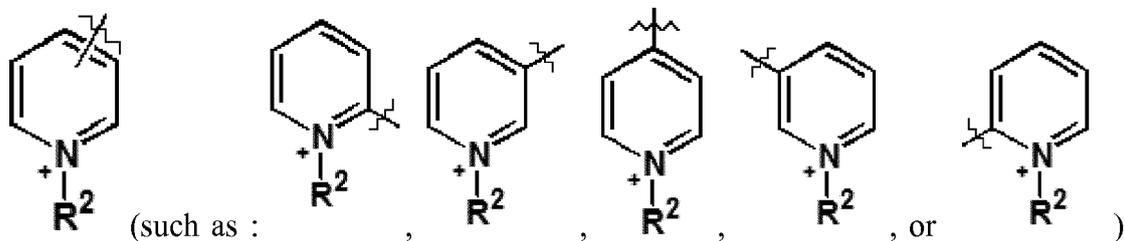


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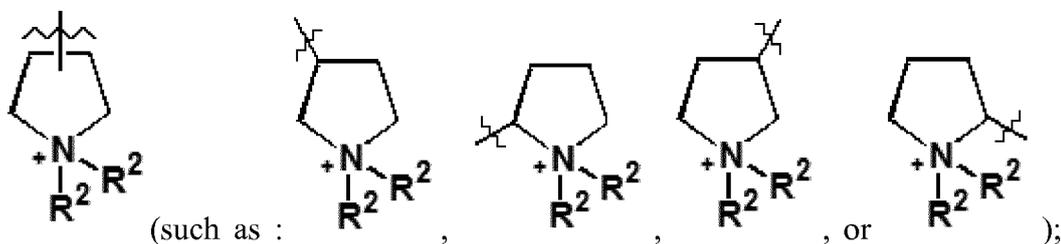
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or

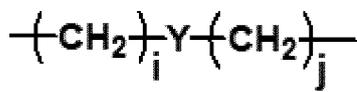
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40 A<sup>-</sup> can be F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X is

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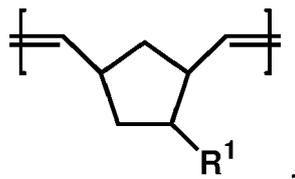


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i and j can be independently 0, or an integer from 1 to 6, Y can be -O-, -S-, -CH<sub>2</sub>-, or -NH-; and, R<sup>2</sup> and R<sup>3</sup> can be independently hydrogen, or C<sub>1-8</sub> alkyl group (such as : methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl). In addition, the second repeat unit can be

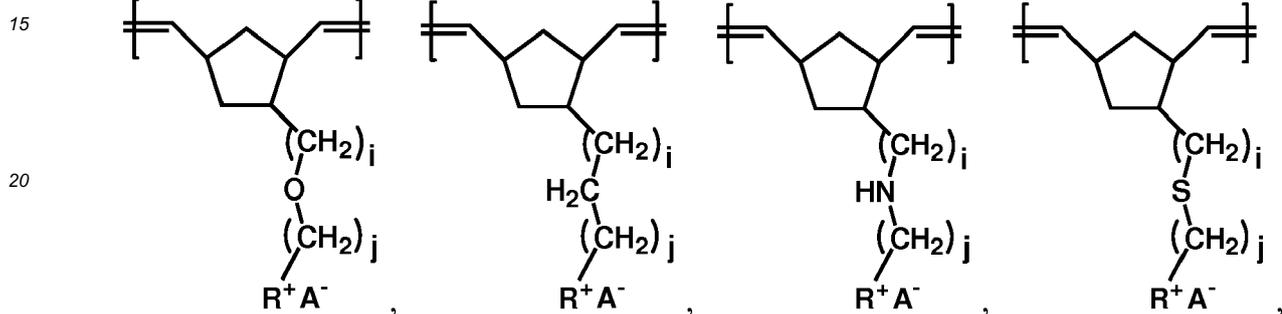
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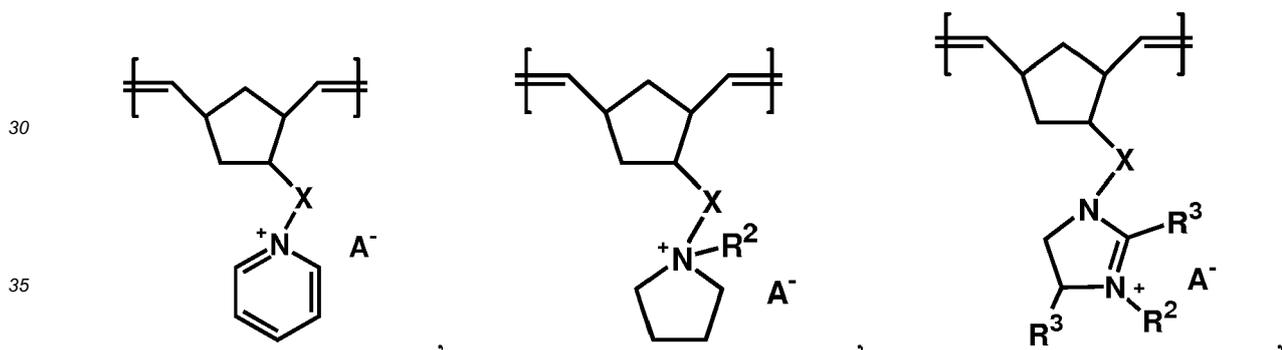


10 wherein  $R^1$  can be independently  $C_{1-8}$  alkyl group (such as methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl).

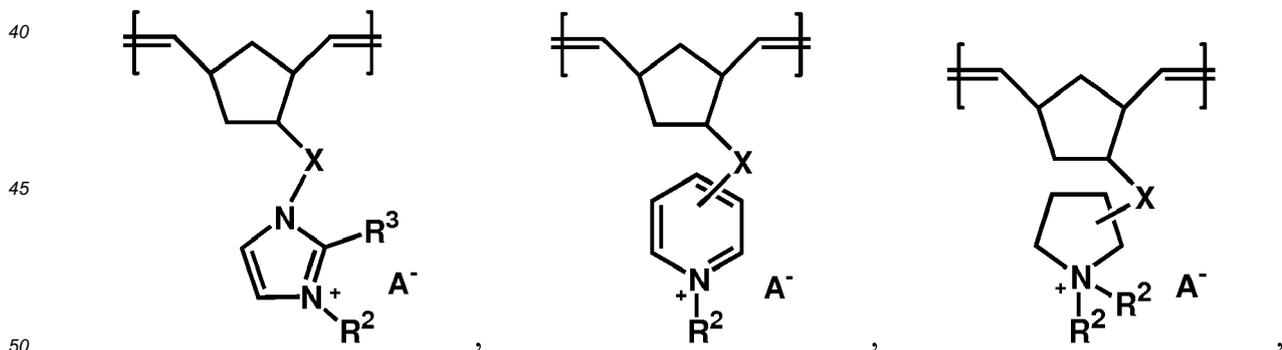
**[0010]** According to embodiments of the disclosure, the first repeat unit can be



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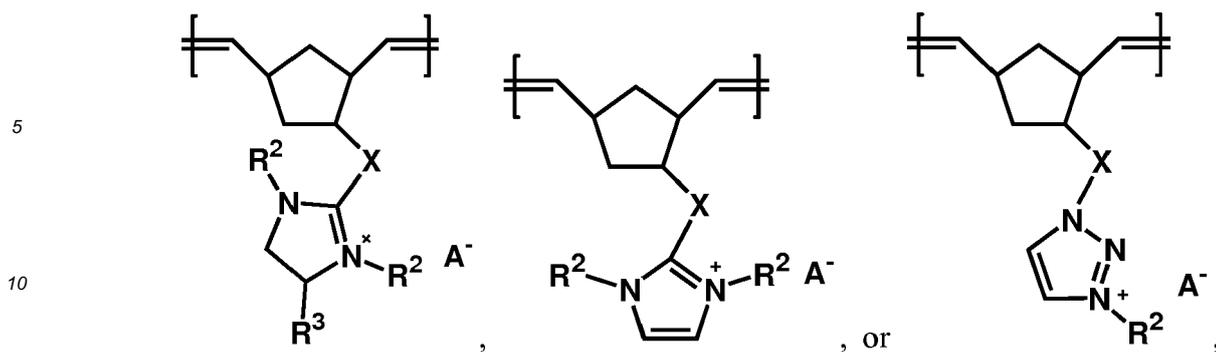


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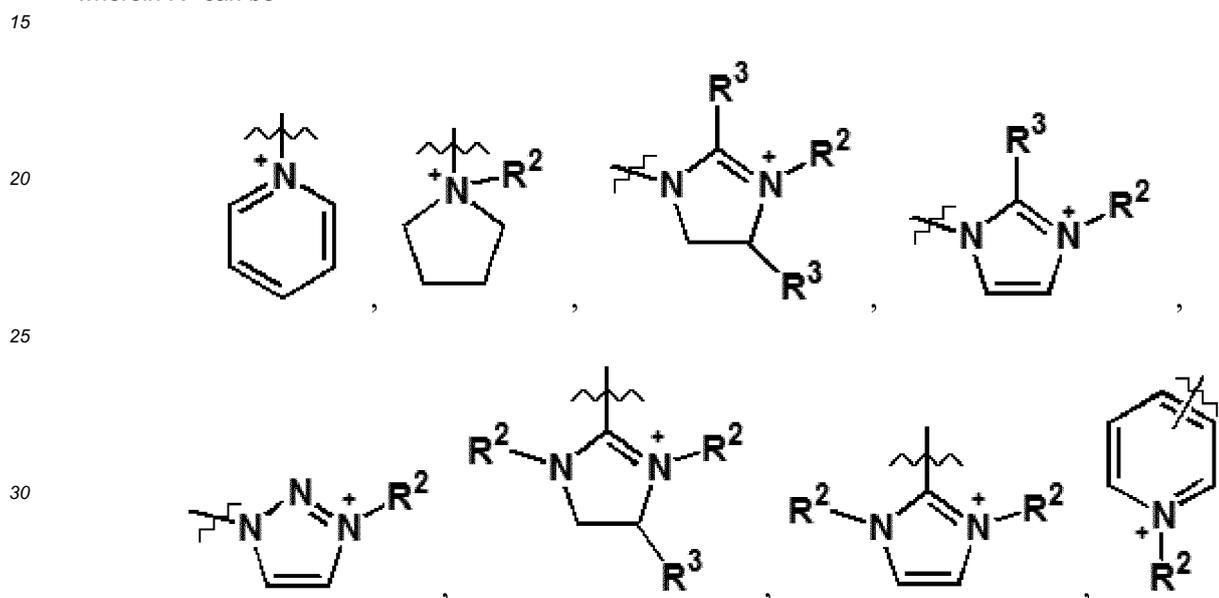


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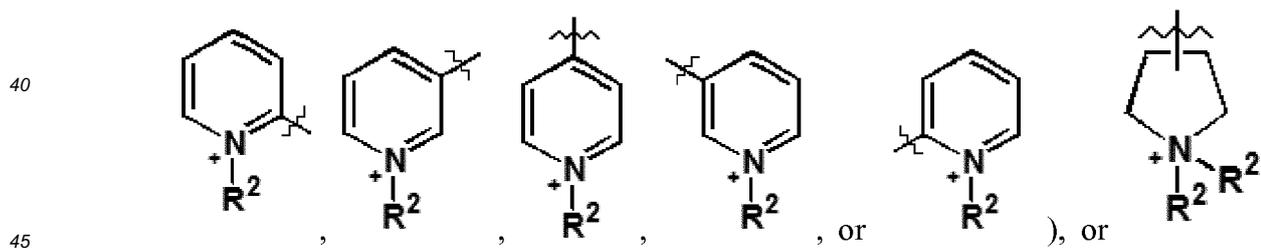
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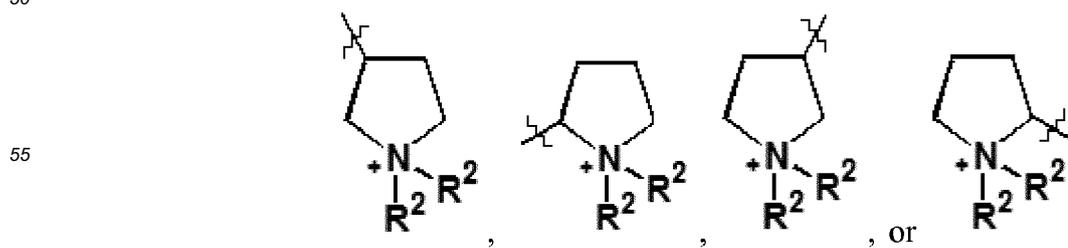
wherein R<sup>+</sup> can be



(such as



(such as

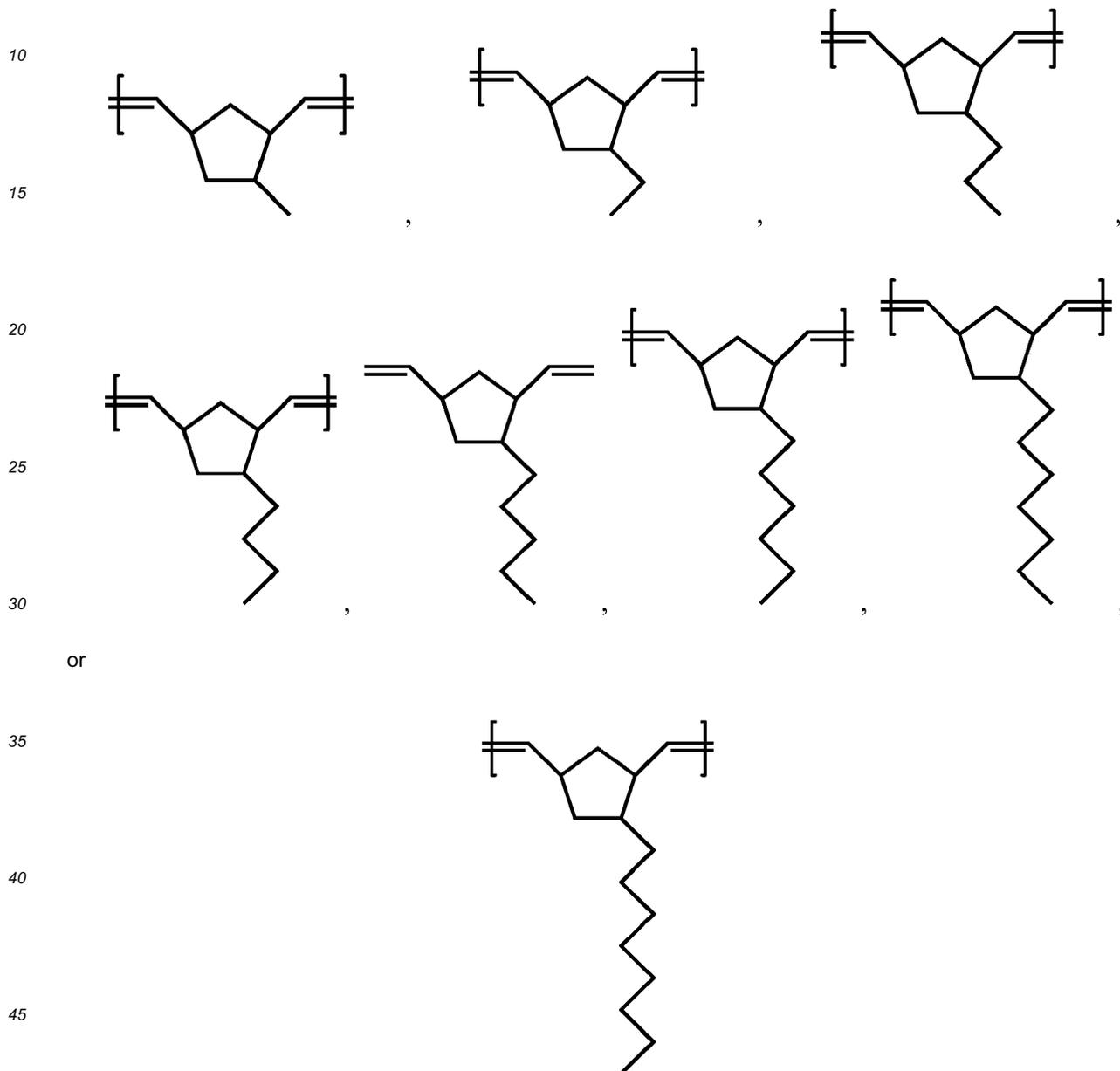


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); A<sup>-</sup> can be F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X is (CH<sub>2</sub>)<sub>i</sub>Y(CH<sub>2</sub>)<sub>j</sub>; Y can be -O-, -S-, -CH<sub>2</sub>-, or -NH-; i and j can be independently 0, or an integer from 1 to 6; and, R<sup>2</sup> and R<sup>3</sup> can be independently hydrogen, or C<sub>1-8</sub> alkyl group.

5 [0011] According to embodiments of the disclosure, the polymer of the disclosure has a molecular weight (such as number average molecular weight) between about 100, 000 and 250,000.

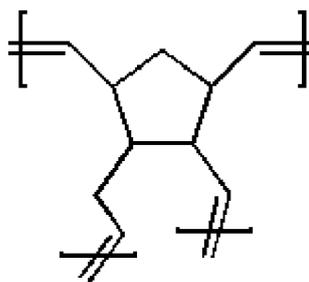
[0012] According to embodiments of the disclosure, the second repeat unit can be



50 [0013] According to embodiments of the disclosure, the ratio between the first repeat unit and the second repeat unit of the polymer can be adjusted to achieve the desired characteristics of the polymer. For example, the ratio between the first repeat unit and the second repeat unit can be increased in order to enhance the electrical conductivity and the anion exchange capacity of the polymer. On the other hand, the ratio between the first repeat unit and the second repeat unit can be decreased in order to enhance the solubility, the mechanical strength, and the solvent selectivity of the polymer. The ratio between the first repeat unit and the second repeat unit can be between about 1:99 and 99:1, such as between about 10:90 and 90:10, between about 20:80 and 80:20, or between about 30:70 and 70:30.

55 [0014] According to embodiments of the disclosure, the polymer of the disclosure can further include a third repeat unit, wherein the third repeat unit can be

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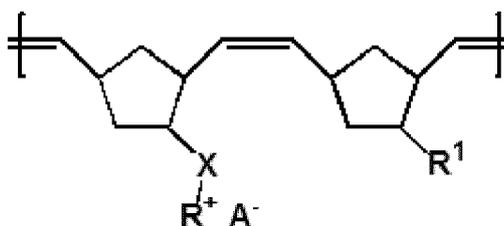
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The portion represented by  of the first repeat unit, the second repeat unit, or the third repeat unit is bonded to

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the portion represented by  of the other first repeat unit, the other second repeat unit, or the other third repeat unit. In addition, the first repeat unit, the second repeat unit, and the third repeat unit can be arranged in a random fashion. For example, the polymer of the disclosure can have a moiety represented by

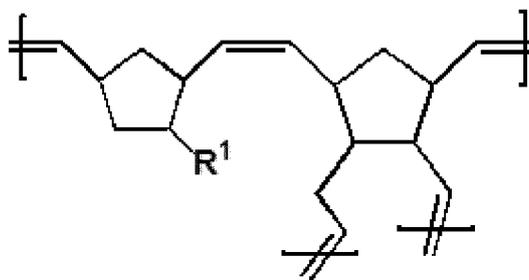
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a moiety represented by

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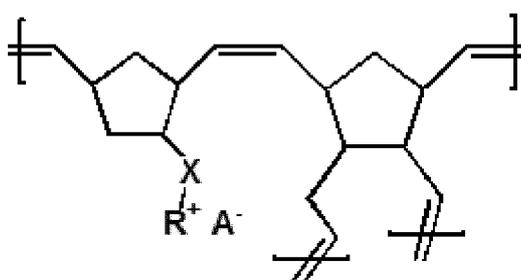


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or a moiety represented by

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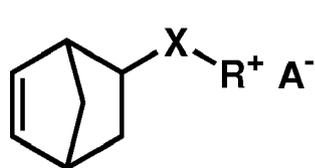


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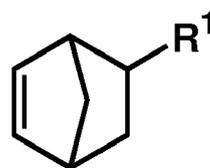
**[0015]** According to embodiments of the disclosure, the ratio between the third repeat unit and the sum of the first

repeat unit and the second repeat unit can be between about 0.1:100 and 5:100, such as between about 0.5:100 and 4:100, or between about 0.5:100 and 3:100. Due to the introduction of the third repeat unit, the polymer can have improved cross-linking degree and mechanical strength by adopting the third repeat unit. In addition, when the ratio between the third repeat unit and the sum of the first repeat unit and the second repeat unit is too high, the polymer would have too high a cross-linking degree and too high a molecular weight and cannot be redissolved in the subsequent process solvent.

[0016] According to embodiments of the disclosure, the disclosure provides a method for preparing the aforementioned polymer. The method includes subjecting a composition to a polymerization, such as a ring opening metathesis polymerization (ROMP). The composition can include a first monomer having a structure of Formula (I) and a second monomer having a structure of Formula (II)

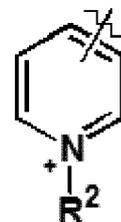
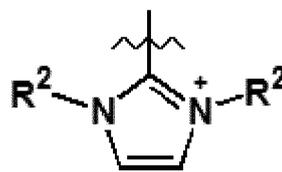
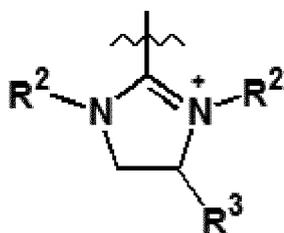
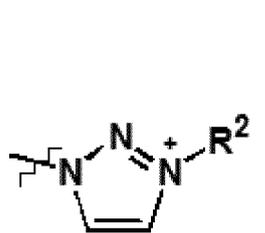
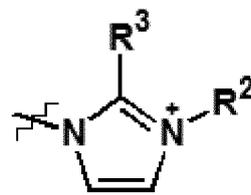
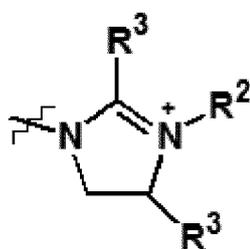
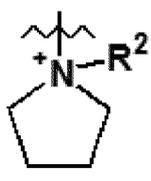
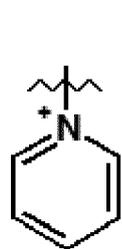


Formula (I)

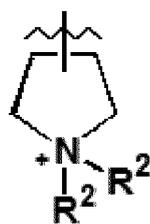


Formula (II)

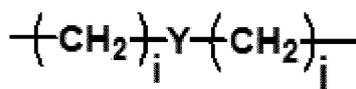
wherein, R<sup>+</sup> can be



, or



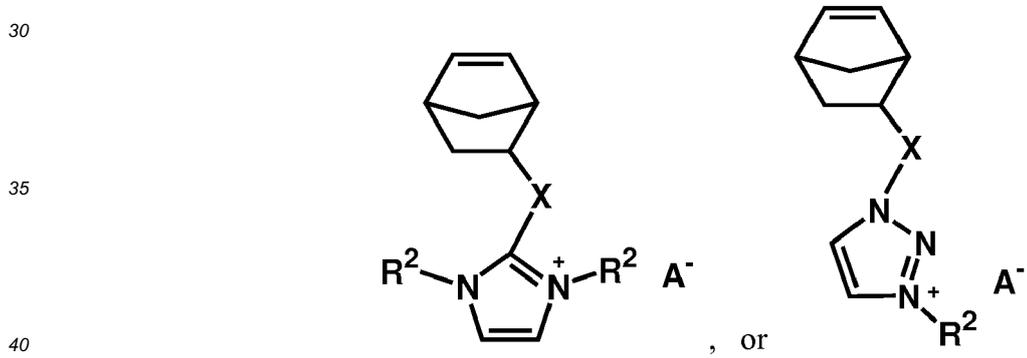
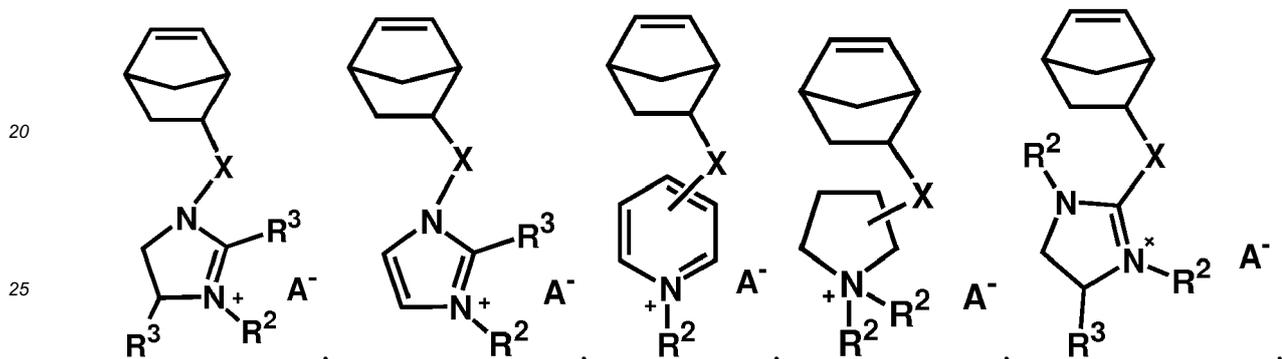
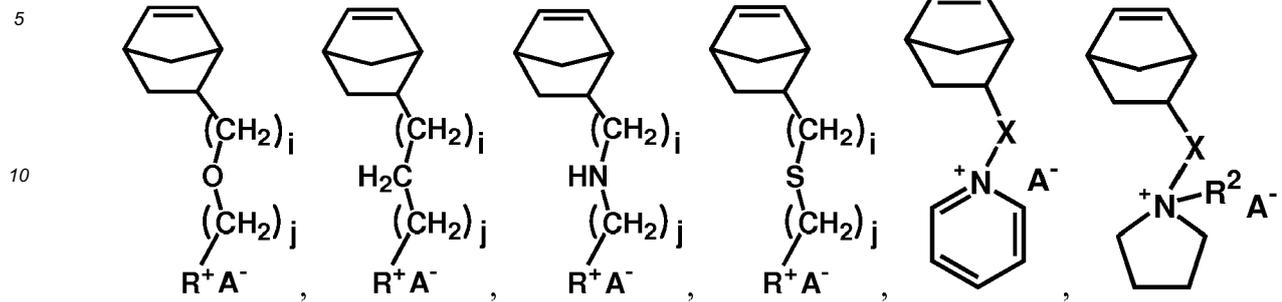
A<sup>-</sup> can be F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X can be



i and j can be independently 0, or an integer from 1 to 6, Y can be -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> can be independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> can be independently hydrogen, or C<sub>1-8</sub> alkyl group. In addition, a catalyst (such as the

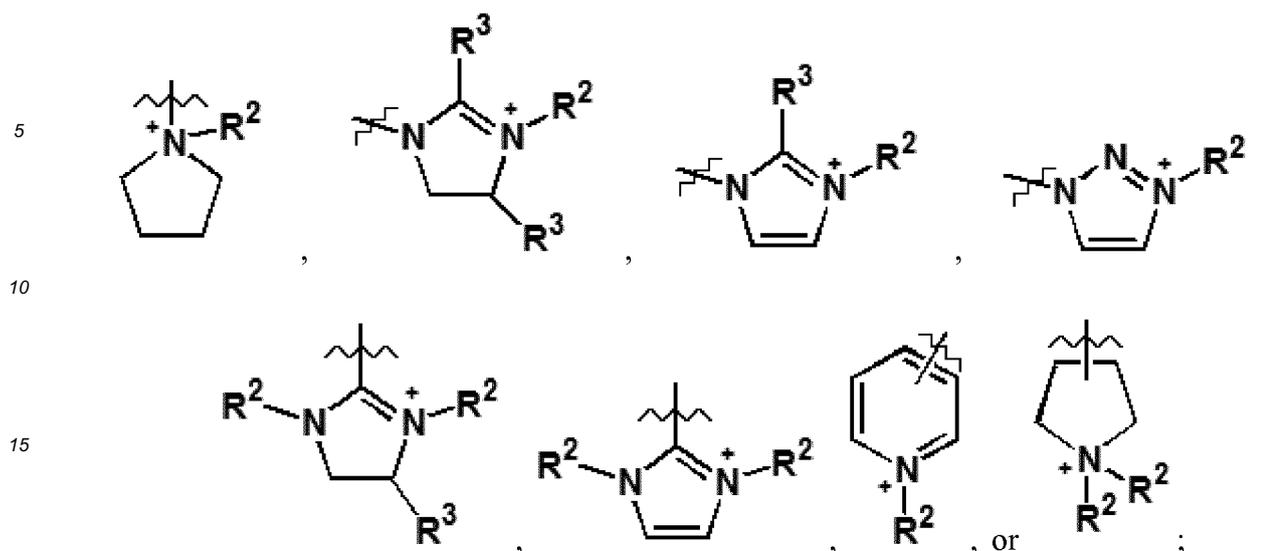
first generation or second generation Grubb's catalysts) can be further employed during the polymerization.

[0017] According to embodiments of the disclosure, the first monomer can be



wherein, R<sup>+</sup> can be

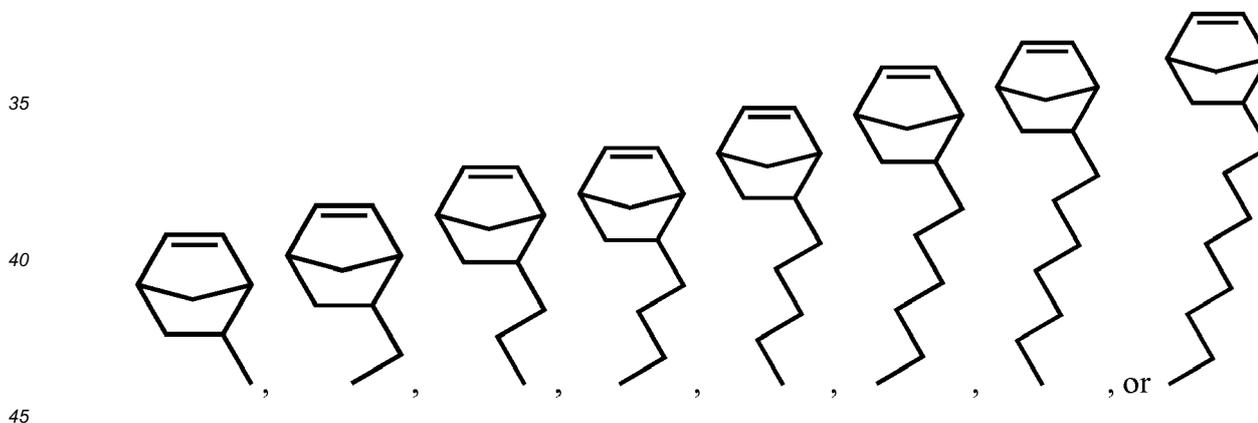




A<sup>-</sup> can be F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X can be



i and j can be independently 0, or an integer from 1 to 6, Y is -O-, -S-, -CH<sub>2</sub>-, or -NH-; and, R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, or C<sub>1-8</sub> alkyl group (such as : methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl). In addition, the second monomer can be



**[0018]** According to embodiments of the disclosure, the molar ratio between the first monomer and the second monomer can be between about 1:99 and 99:1, such as between about 10:90 and 90:10, between about 20:80 and 80:20, or between about 30:70 and 70:30.

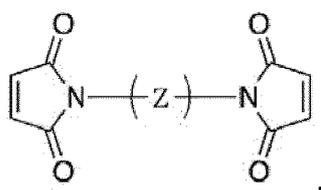
**[0019]** In addition, according to embodiments of the disclosure, the composition can further include a third monomer, wherein the third monomer can be



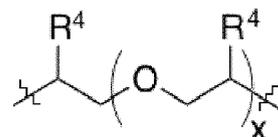
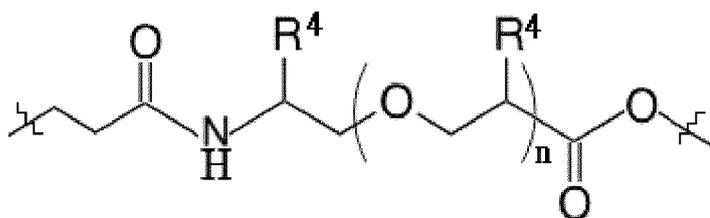
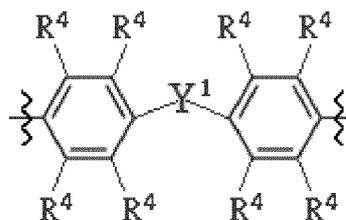
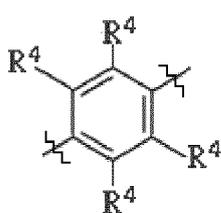
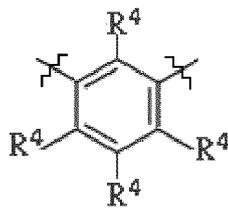
The molar ratio between the third monomer and the sum of the first monomer and the second monomer can be between about 0.1:100 and 5:100, such as between about 0.5:100 and 4:100, or between about 0.5:100 and 3:100.

**[0020]** According to embodiments of the disclosure, the polymer of the disclosure can be used to prepare an ion exchange membrane. The method for preparing the ion exchange membrane includes the following steps. First, a composition is provided, wherein the composition includes the aforementioned polymer and a cross-linking agent. In addition, the composition can further include a solvent, and the composition has a solid content between about 5wt% and 50 wt%. In the composition, the cross-linking agent can have a weight percentage between about 1wt% and 30wt% (such as between about 5wt% and 30wt%, or between about 5wt% and 25wt%), based on the weight of the polymer. Next, the composition is subjected to a mixing and distributing process. Next, the composition is coated on a substrate (such as a glass substrate) to form a coating. Next, the coating is baked to remove most of the solvent. Next, the coating formed on the substrate is baked in a high temperature oven to remove residual solvent. Finally, the coating is immersed in potassium hydroxide aqueous solution and deionized water for 1-3 hours sequentially. After drying, the ion exchange membrane of the disclosure is obtained.

**[0021]** The cross-linking agent can be a compound having at least two maleimide groups. For example, the cross-linking agent can be a compound having two maleimide groups. According to embodiments of the disclosure, the compound having two maleimide groups can be

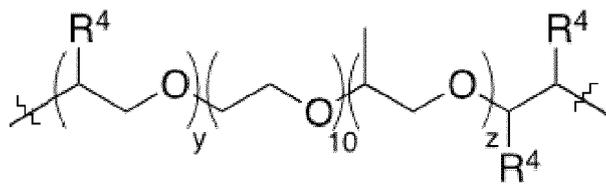


wherein Z can be



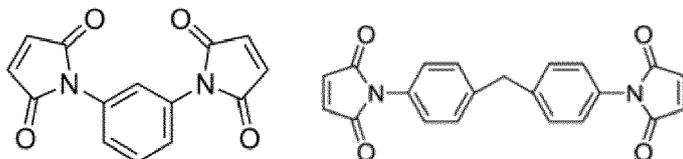
or

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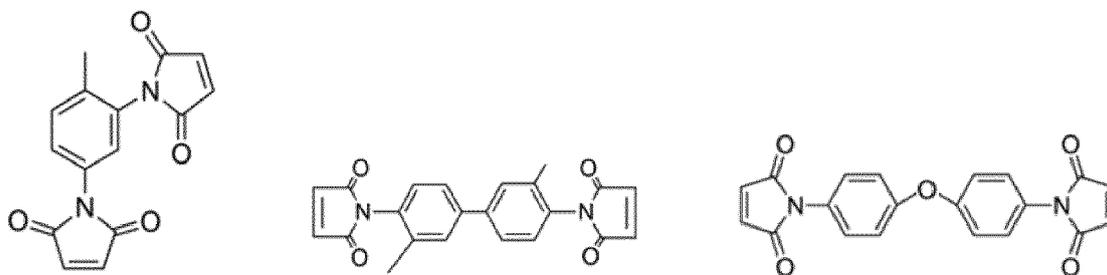


10 wherein Y<sup>1</sup> can be single bond, -O-, -S-, -CH<sub>2</sub>-, or -NH-, R<sup>4</sup> can be independently hydrogen, or C<sub>1-4</sub> alkyl group; n ≥ 1; x can be an integer from 1 to 12, y and z can be independently an integer from 1 to 5. For example, the cross-linking agent can be

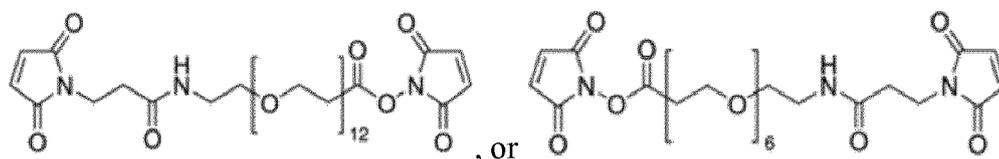
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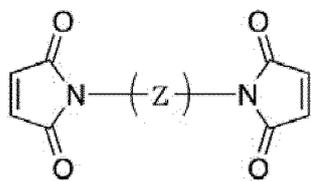
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40 **[0022]** In addition, according to embodiments of the disclosure, the cross-linking agent can be a polymeric cross-linking agent having at least two maleimide groups. The polymeric cross-linking agent can be a reaction product of a compound (a) and a compound (b). The compound (a) can be

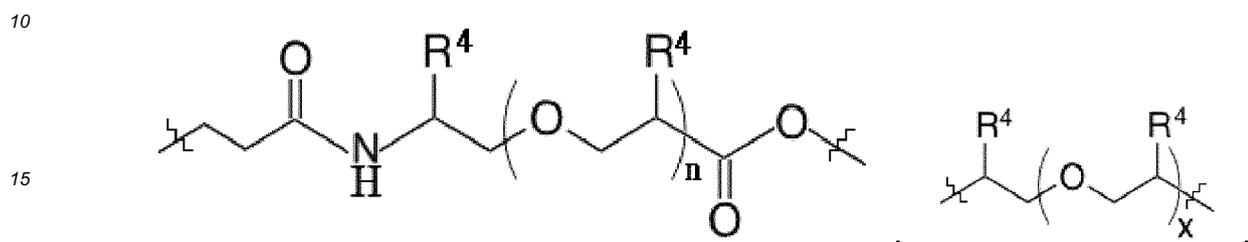
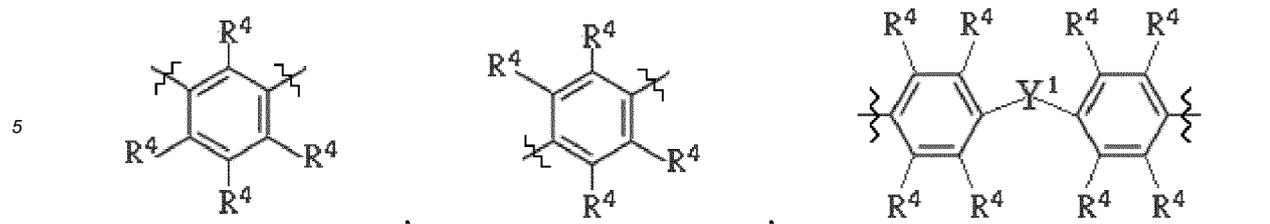
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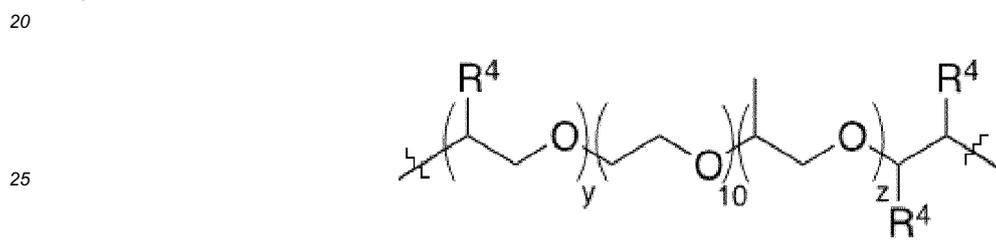
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wherein Z can be

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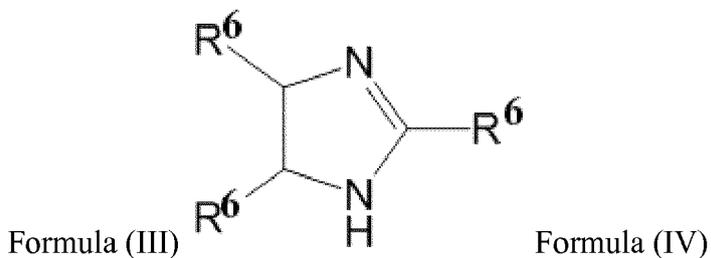
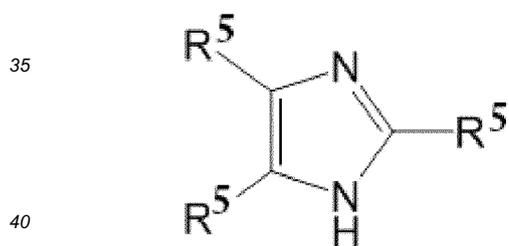


or



30

wherein  $Y^1$  can be single bond, -O-, -S-, - $CH_2$ -, or -NH-,  $R^4$  can be independently hydrogen, or  $C_{1-4}$  alkyl group; and,  $n \geq 1$ ; x can be an integer from 1 to 12; and, y and z can be independently an integer from 1 to 5. The compound (b) can be a compound represented by Formula (III) or Formula (IV)



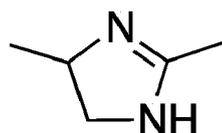
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, wherein  $R^5$  is independently hydrogen, or  $C_{1-4}$  alkyl group; and,  $R^6$  is independently hydrogen, or  $C_{1-4}$  alkyl group. For example, the compound (b) can be



or

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**[0023]** The polymeric cross-linking agent and the polymer can form an interpenetrating polymer network, thereby enhancing the mechanical strength and dimensional stability.

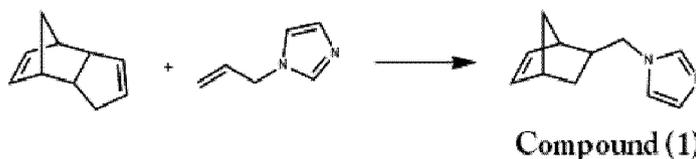
**[0024]** Below, exemplary embodiments will be described in detail so as to be easily realized by a person having ordinary knowledge in the art. The disclosure concept may be embodied in various forms without being limited to the exemplary embodiments set forth herein. Descriptions of well-known parts are omitted for clarity.

Preparation of monomer with cationic group

15 Preparation Example 1

**[0025]** 10ml of dicyclopentadiene (0.074 mmol) and 20.15ml of 1-allylimidazole (0.186 mmol) were added into a high-pressure reactor. After stirring at 180°C for 8 hours, the result was purified by fractionation and column chromatography (using ethyl acetate (EA) and hexane (9:1) as the eluent), obtaining Compound (1) (colorless transparent viscous liquid). The synthesis pathway of the above reaction was as follows:

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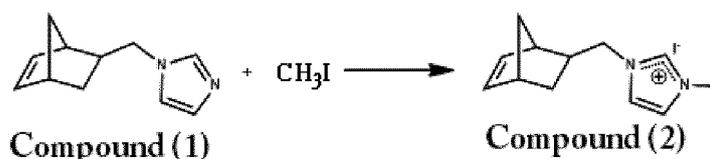
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**[0026]** Compound (1) was analyzed by nuclear magnetic resonance (NMR) spectroscopy and the result is as follows: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 7.46 (d, J = 15.3, 1H), 6.98 (m, 2H), 6.12 (m, 2H), 3.79 (m, 2H), 2.66 (m, 3H), 1.89 (m, 1H), 1.33 (m, 2H), 0.62 (m, 1H).

30

**[0027]** Next, 0.5g of Compound (1) (2.87 mmol) and 0.268 ml of methyl iodide (4.30 mmol) were added into a reaction bottle. After stirring at room temperature (about 25°C) for 8 hours and then removing residual methyl iodide by vacuum distillation, Compound (2) (yellow viscous liquid) was obtained. The synthesis pathway of the above reaction was as follows:

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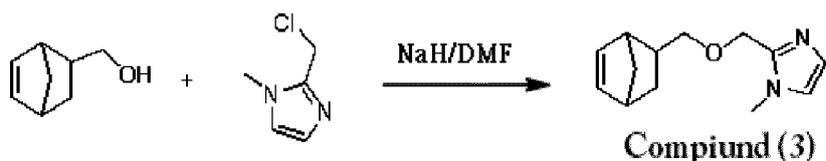
**[0028]** Compound (2) was analyzed by nuclear magnetic resonance (NMR) spectroscopy and the result is as follows: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>): δ 10.03 (d, J = 12.0 Hz, 1H), 7.42 (m, 2H), 6.21 (m, 2H), 4.19 (m, 5H), 2.74 (m, 3H), 1.99 (m, 1H), 1.41 (m, 2H), 0.67 (m, 1H)

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Preparation Example 2

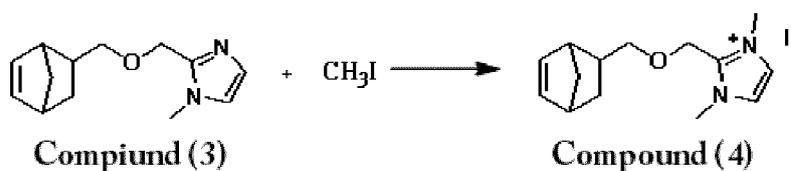
**[0029]** 15ml of dimethylformamide (DMF) was added into a reaction bottle. Next, 1.7g of sodium hydride (NaH) (0.00427 mol) was added into the reaction bottle at 0°C. Next, 2.122g of 5-Norbornene-2-methanol (0.0171 mol) was added into the reaction bottle at 0°C. After stirring, 2g of 1-methyl-2-(chloromethyl) imidazole (0.0154 mol) was added into the reaction bottle. After stirring for 12 hours, water was added into the reaction bottle to quench the reaction, and then the result was extracted by dichloromethane. After concentration, the result was purified by fractionation, obtaining Compound (3). The synthesis pathway of the above reaction was as follows:

55



10 **[0030]** Compound (3) was analyzed by nuclear magnetic resonance (NMR) spectroscopy and the result is as follows:  
 $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  6.90 (s, 2H), 6.10-5.76 (m, 2H), 4.59-4.81 (m, 2H), 3.71 (s, 3H), 3.51-3.00(m, 2H), 2.86-2.69(m, 2H), 2.33(m, 1H), 1.84-1.66 (m, 1H), 1.41-1.10(m, 2H), 0.47-0.43(m, 1H)

15 **[0031]** Next, 2g of Compound (3) (9 mmol) was added into a reaction bottle and dissolved in dichloromethane. Next, 1 ml of methyl iodide (17 mmol) was added into the reaction bottle. After stirring at room temperature for 12 hours, residual methyl iodide and solvent were removed, obtaining Compound (4) (yellow viscous liquid). The synthesis pathway of the above reaction was as follows:

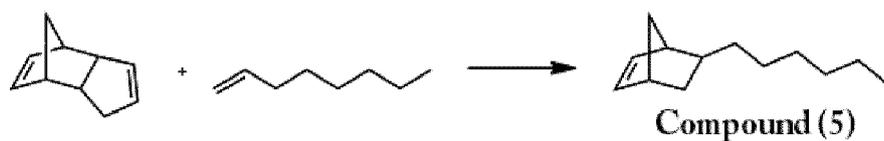


25 **[0032]** Compound (4) was analyzed by nuclear magnetic resonance (NMR) spectroscopy and the result is as follows:  
 $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.45 (s, 2H), 6.18-5.84(m, 2H), 4.90(s, 2H), 3.98(s, 6H), 3.68-3.20(m, 2H), 2.35(m, 1H), 1.86-1.78(m, 1H), 1.46-1.14(m, 4H), 0.52-0.51(m, 1H)

Preparation of monomer with non-ionic group

30 Preparation Example 3

35 **[0033]** 13.4ml of dicyclopentadiene (0.1 mmol) and 36ml of 1-octene (0.23 mmol) were added into a high-pressure reactor. After stirring at 240°C for 12 hours, the result was filtered through neutral alumina to remove the yellow suspension. Next, the result was purified by fractionation, obtaining Compound (5) (colorless transparent viscous liquid). The synthesis pathway of the above reaction was as follows:

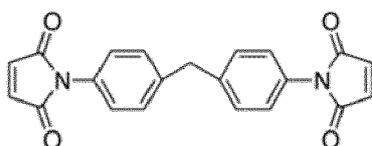


45 **[0034]** Compound (5) was analyzed by nuclear magnetic resonance (NMR) spectroscopy and the result is as follows:  
 $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ):  $\delta$  6.08 (m, 1H, endo), 6.04 (m, 1H, exo), 5.90 (m, 1H, endo), 2.67-2.77 (m, 2H), 2.48 (m, 1H, exo), 1.97 (m, 1H, endo), 1.80 (m, 1H, endo), 1.14-1.38 (m, 11H), 0.82-0.90(m, 3H), 0.43-0.50(m, 1H, endo)

Preparation of cross-linking agent

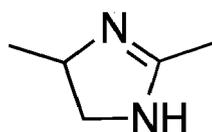
50 Preparation Example 4

**[0035]** 2.73g of



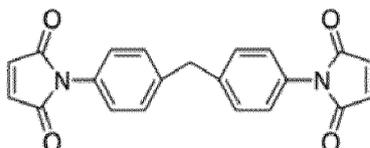
and 0.37g of

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were added into a reaction bottle, wherein the molar ratio of the

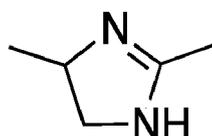
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and

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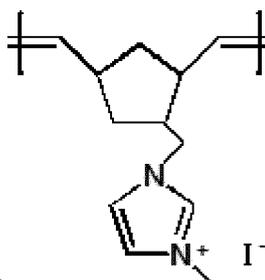
was 2:1). Next, 97g of dimethylacetamide (DMAc) was added into the reaction bottle. After stirring at 100-150 °C for 5-10 hours, Polymeric cross-linking agent (1) was obtained.

Preparation of polymer

Example 1

**[0036]** 3.08g of Compound (2) (9.74 mmole) and 0.19g of Compound (5) (1.08 mmole) were added into a reaction bottle under a nitrogen atmosphere, wherein the molar ratio of Compound (2) and Compound (5) was about 9:1. Next, 30 ml of dichloromethane was added into the reaction bottle. Next, Grubbs's solution (9.2mg, dissolved in 6ml of dichloromethane) was slowly added into the reaction bottle at 30°C. After stirring for 4 hours, the result was slowly added into 250 ml of ethyl ether. After stirring for about 30 minutes and concentration, the result was washed with 100ml of acetone, and then the solid was collected. After drying, Polymer (1) (having a repeat unit represented by

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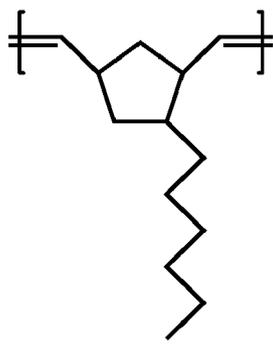


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and a repeat unit represented by

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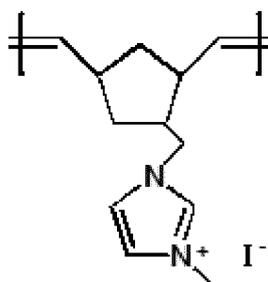
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wherein the ratio of the repeat unit represented by

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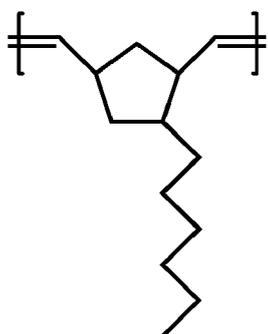


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and the repeat unit represented by

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was about 9:1) was obtained. After measurement, the number average molecular weight (Mn) of Polymer (1) is about 110, 000, and the polydispersity index (PDI) of Polymer (1) is about 1.4.

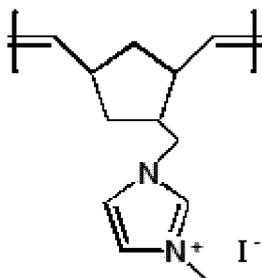
45 Example 2

**[0037]** Example 2 was performed in the same manner as in Example 1 except that the molar ratio of Compound (2) and Compound (5) was about 8:2, obtaining Polymer (2) (the ratio of the repeat unit represented by

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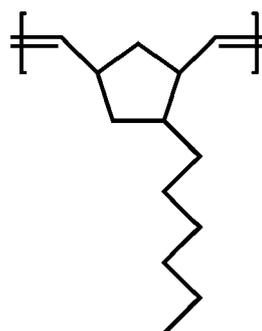
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and the repeat unit represented by

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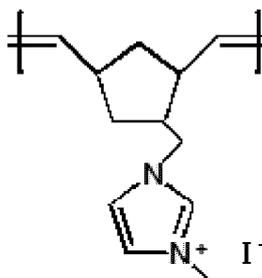
was about 8:2).

Example 3

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**[0038]** Example 3 was performed in the same manner as in Example 1 except that the molar ratio of Compound (2) and Compound (5) was about 7:3, obtaining Polymer (3) (the ratio of the repeat unit represented by

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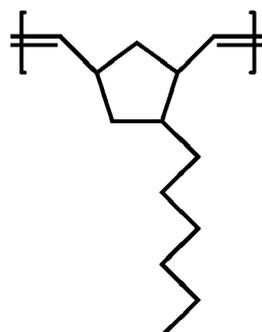


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and the repeat unit represented by

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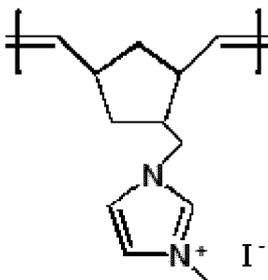
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was about 7:3).

Example 4

5 **[0039]** Example 4 was performed in the same manner as in Example 1 except that the molar ratio of Compound (2) and Compound (5) was about 4:6, obtaining Polymer (4) (the ratio of the repeat unit represented by

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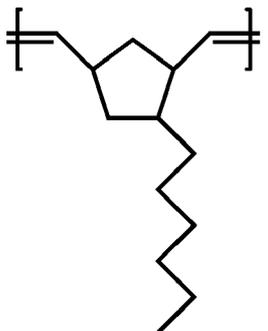


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and the repeat unit represented by

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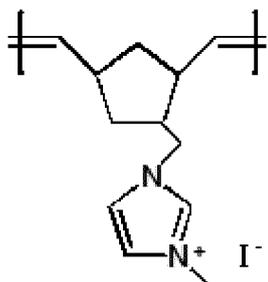
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was about 4:6).

Example 5

40 **[0040]** Example 5 was performed in the same manner as in Example 1 except that the molar ratio of Compound (2) and Compound (5) was about 2:8, obtaining Polymer (5) (the ratio of the repeat unit represented by

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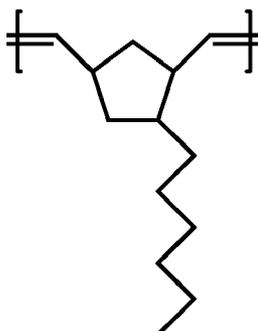
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and the repeat unit represented by

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was about 2:8).

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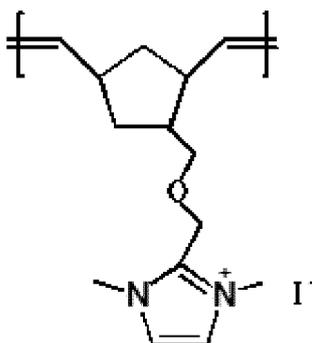
#### Example 6

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**[0041]** 3.53g of Compound (4) (9.74 mmole) and 0.19g of Compound (5) (1.08 mmole) were added into a reaction bottle under a nitrogen atmosphere, wherein the molar ratio of Compound (4) and Compound (5) was about 9:1. Next, 30 ml of dichloromethane was added into the reaction bottle. Next, Grubbs's solution (9.2mg, dissolved in 6ml of dichloromethane) was slowly added into the reaction bottle at 30°C. After stirring for 4 hours, the result was slowly added into 250 ml of ethyl ether. After stirring for about 30 minutes and concentration, the result was washed with 100ml of acetone, and then the solid was collected. After drying, Polymer (6) (having a repeat unit represented by

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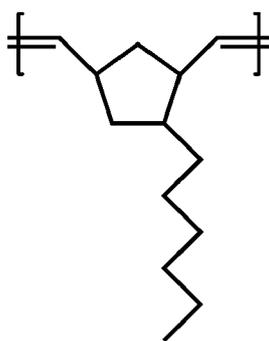
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and a repeat unit represented by

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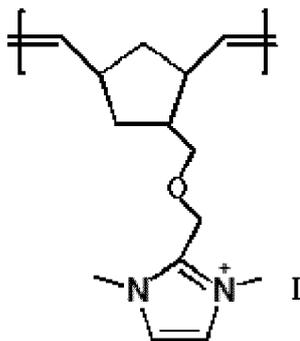
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wherein the ratio of the repeat unit represented by

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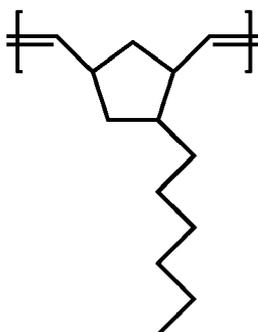
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and the repeat unit represented by

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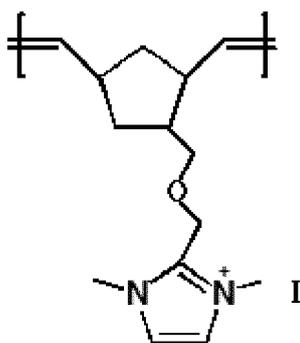
was about 9:1) was obtained.

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Example 7

**[0042]** Example 7 was performed in the same manner as in Example 6 except that the molar ratio of Compound (4) and Compound (5) was about 6:4, obtaining Polymer (7) (the ratio of the repeat unit represented by

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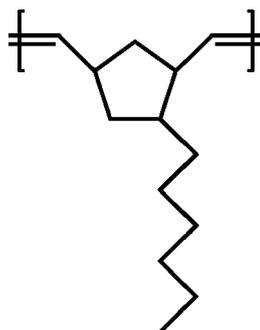
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and the repeat unit represented by

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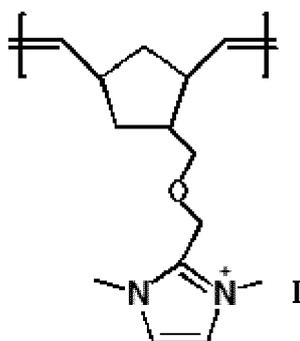
was about 6:4).

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#### Example 8

**[0043]** Example 8 was performed in the same manner as in Example 6 except that the molar ratio of Compound (4) and Compound (5) was about 3:7, obtaining Polymer (8) (the ratio of the repeat unit represented by

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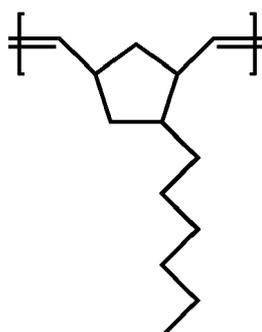


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and the repeat unit represented by

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was about 3:7).

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#### Example 9

**[0044]** 3.08g of Compound (2) (9.74 mmole), 0.19g of Compound (5) (1.08 mmole), and 12mg of dicyclopentadiene (0.097 mmole) were added into a reaction bottle under a nitrogen atmosphere, wherein the molar ratio of Compound (2), Compound (5), and dicyclopentadiene was about 9:1:0.09. Next, 30 ml of dichloromethane was added into the reaction bottle. Next, Grubbs's solution (9.2mg, dissolved in 6ml of dichloromethane) was slowly added into the reaction bottle at 30°C. After stirring for 4 hours, the result was slowly added into 250 ml of ethyl ether. After stirring for about 30 minutes and concentration, the result was washed with 100ml of acetone, and then the solid was collected. After drying,

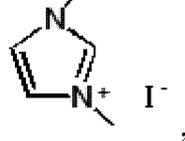
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Polymer (9) (having a repeat unit represented by

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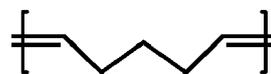
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a repeat unit represented by

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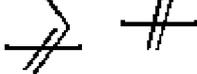
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and a repeat unit represented by

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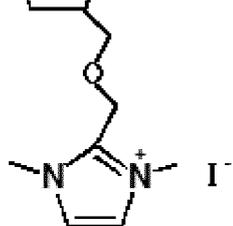


wherein the ratio of the repeat unit represented by

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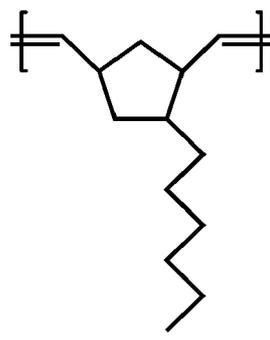
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the repeat unit represented by

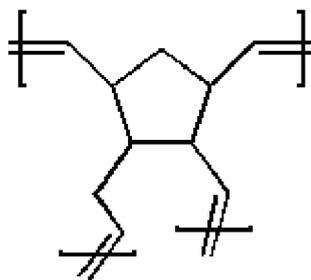
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and the repeat unit represented by

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was about 9:1:0.09) was obtained.

Preparation of anion exchange membrane

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Example 10

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**[0045]** 100 parts by weight of polymer (1) (prepared from Example 1) was added into a reaction bottle, and dissolved in 667 parts by weight of dimethylacetamide (DMAc). Next, 10 parts by weight of polymeric cross-linking agent (1) (prepared from Preparation Example 4) was added into the reaction bottle. Next, the result was mixed and distributed via a high speed homogenizer, and then defoamed, obtaining a solution. Next, the solution was coated on a glass substrate via spin coating, forming a coating. Next, the coating was baked at 40-150°C to remove most of the solvent. Next, the coating was baked at 120-200°C for 1-6 hours to remove residual solvent. Next, the coating was immersed in potassium hydroxide aqueous solution at room temperature for 1.5 hours and deionized water at room temperature for 1.5 hours sequentially to ensure no solvent remained in the coating. After drying, Anion exchange membrane (1) was obtained. Next, the ionic conductivity of Anion exchange membrane (1) was measured, and the result is shown in Table 1.

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Example 11-14

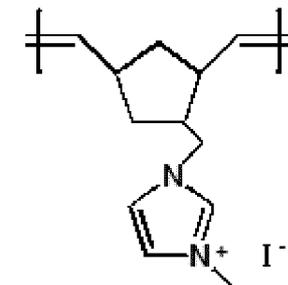
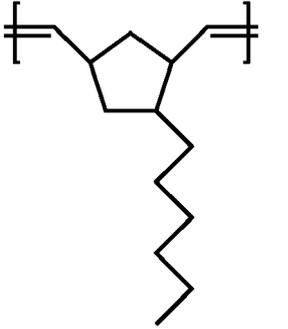
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**[0046]** Examples 11-14 were performed in the same manner as in Example 10 except that Polymers (2)-(5) were substituted for Polymer (1) respectively, obtaining Anion exchange membranes (2)-(5). Next, the ionic conductivity of Anion exchange membranes (2)-(5) were measured, and the results are shown in Table 1. Furthermore, the tensile strength and anti-rupture strength of Anion exchange membrane (3) were measured according to ASTM D882-02, and the result is shown in Table 2.

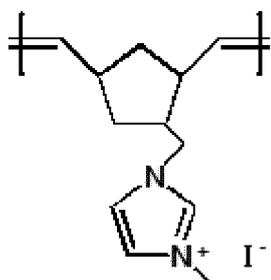
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Table 1

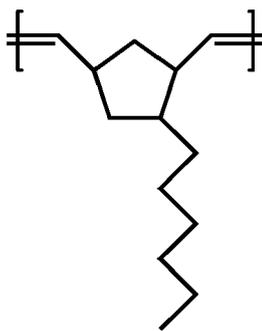
|                             | <p>ratio of the repeat unit represented by</p>  <p>and the</p>  <p>repeat unit represented by</p> | ionic conductivity (S/cm) |
|-----------------------------|---|---------------------------|
| Anion exchange membrane (1) | 9:1   | 0.13                      |
| Anion exchange membrane (2) | 8:2   | --                        |
| Anion exchange membrane (3) | 7:3   | 0.06                      |
| Anion exchange membrane (4) | 4:6   | 0.05                      |
| Anion exchange membrane (5) | 2:8   | 0.005                     |

[0047] As shown in Table 1, with the increase of the ratio of the repeat unit represented by



and the repeat unit represented by

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the ionic conductivity of the anion exchange membrane is improved.

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Example 1 5

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**[0048]** Example 15 was performed in the same manner as in Example 12 except that 7 parts by weight of Polymeric cross-linking agent (1) was substituted for 10 parts by weight of Polymeric cross-linking agent (1), obtaining Anion exchange membrane (6). Next, the tensile strength and anti-rupture strength of Anion exchange membrane (6) were measured according to ASTM D882-02, and the result is shown in Table 2.

Example 16

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**[0049]** Example 16 was performed in the same manner as in Example 12 except that 20 parts by weight of Polymeric cross-linking agent (1) was substituted for 10 parts by weight of Polymeric cross-linking agent (1), obtaining Anion exchange membrane (7). Next, the tensile strength and anti-rupture strength of Anion exchange membrane (7) were measured according to ASTM D882-02, and the result is shown in Table 2.

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Example 17

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**[0050]** Example 17 was performed in the same manner as in Example 12 except that 25 parts by weight of Polymeric cross-linking agent (1) was substituted for 10 parts by weight of Polymeric cross-linking agent (1), obtaining Anion exchange membrane (8). Next, the tensile strength and anti-rupture strength of Anion exchange membrane (8) were measured according to ASTM D882-02, and the result is shown in Table 2.

Table 2

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|                             | polymeric cross- linking agent (parts by weight) | tensile strength (MPa) | anti-rupture strength (MPa) |
|-----------------------------|--|------------------------|-----------------------------|
| Anion exchange membrane (3) | 10   | 25.59                  | 36.57                       |
| Anion exchange membrane (6) | 7  | 32.51                  | 44.35                       |
| Anion exchange membrane (7) | 20   | 30.19                  | 45.77                       |
| Anion exchange membrane (8) | 25   | 35.22                  | 47.32                       |

**[0051]** As shown in Table 2, with the increase of the concentration of the polymeric cross-linking agent, the mechanical strength (such as tensile strength and anti-rupture strength) is improved. Therefore, according to Tables 1 and 2, the anion exchange membrane of the disclosure exhibits superior ionic conductivity and mechanical strength.

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Example 18

**[0052]** 100 parts by weight of polymer (6) (prepared from Example 6) was added into a reaction bottle, and dissolved

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in 667 parts by weight of dimethylacetamide (DMAc). Next, 10 parts by weight of Polymeric cross-linking agent (1) (prepared from Preparation Example 4) was added into the reaction bottle. Next, the result was mixed and distributed via a high speed homogenizer, and then defoamed, obtaining a solution. Next, the solution was coated on a glass substrate via spin coating, forming a coating. Next, the coating was baked at 40-150°C to remove most of the solvent. Next, the coating was baked at 120-200°C for 1-6 hours to remove residual solvent. Next, the coating was immersed in potassium hydroxide aqueous solution at room temperature for 1.5 hours and deionized water at room temperature for 1.5 hours sequentially to ensure no solvent remained in the coating. After drying, Anion exchange membrane (9) was obtained. Next, the ionic conductivity and dimensional stability of Anion exchange membrane (9) was measured, and the result is shown in Table 3.

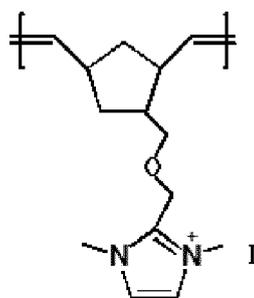
Examples 1 9-20

**[0053]** Examples 19-20 were performed in the same manner as in Example 18 except that Polymers (7) and (8) were substituted for Polymer (6) respectively, obtaining Anion exchange membranes (10) and (11). Next, the ionic conductivity and dimensional stability of Anion exchange membranes (10) and (11) were measured, and the results are shown in Table 3.

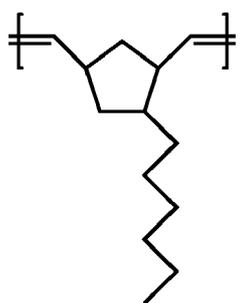
Table 3

|                              | ionic conductivity (S/cm) | dimensional shrinkage (%) (measured at 25°C) |           | dimensional shrinkage (%) (measured at 80°C) |           |
|------------------------------|---------------------------|--|-----------|--|-----------|
|                              |                           | area   | thickness | area   | thickness |
| anion exchange membrane (9)  | 0.09                      | 20   | 9         | 24   | 31        |
| anion exchange membrane (10) | 0.02                      | 0  | 13        | 0  | 4         |
| anion exchange membrane (11) | 0.004                     | 15   | 6         | 4.5  | 21        |

**[0054]** As shown in Table 3, with the increase of the ratio of the repeat unit represented by



and the repeat unit represented by



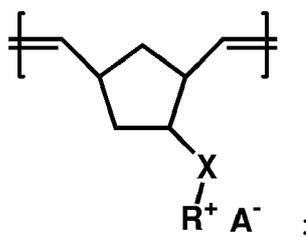
the ionic conductivity of the anion exchange membrane is improved. In addition, the anion exchange membrane of the disclosure also exhibits high dimensional stability.

[0055] Accordingly, due to the introduction of stably cationic group, the polymer of the disclosure exhibits high ionic conductivity. Furthermore, due to the introduction of non-ionic group simultaneously, the polymer of the disclosure also exhibits high solubility, mechanical strength, and solvent selectivity.

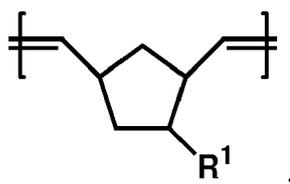
[0056] It will be clear that various modifications and variations can be made to the disclosed methods and materials. It is intended that the specification and examples be considered as exemplary only, with the true scope of the disclosure being indicated by the following claims and their equivalents.

Claims

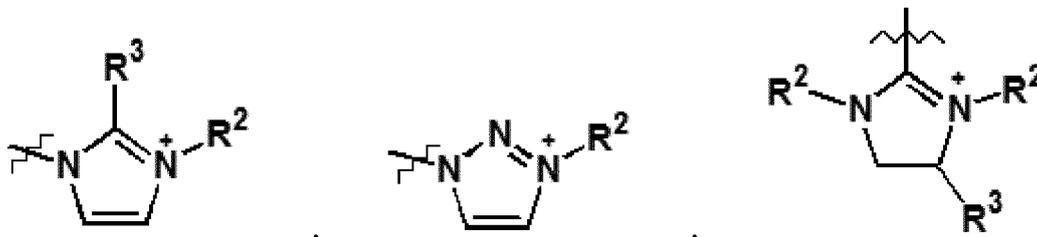
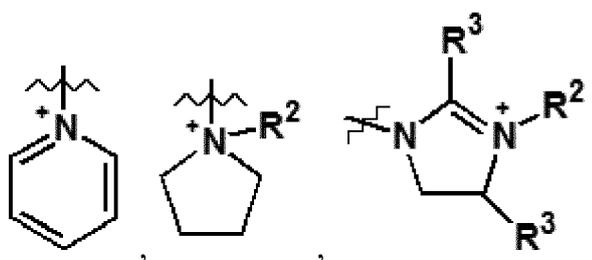
1. A polymer, comprising a first repeat unit and a second repeat unit, wherein the first repeat unit is



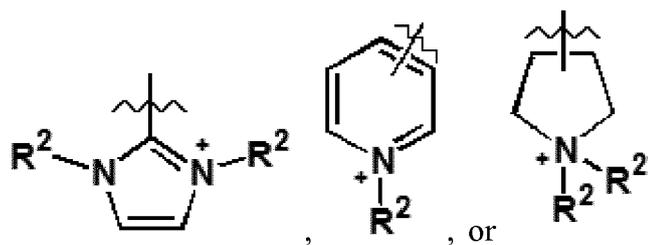
the second repeat unit is



wherein R<sup>+</sup> is



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A<sup>-</sup> is F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X (CH<sub>2</sub>)<sub>i</sub>Y(CH<sub>2</sub>)<sub>j</sub>, i and j is independently 0, or an integer from 1 to 6, Y is -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> is independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, or C<sub>1-8</sub> alkyl group.

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2. The polymer as claimed in claim 1, wherein the ratio between the first repeat unit and the second repeat unit is between 1:99 and 99:1.

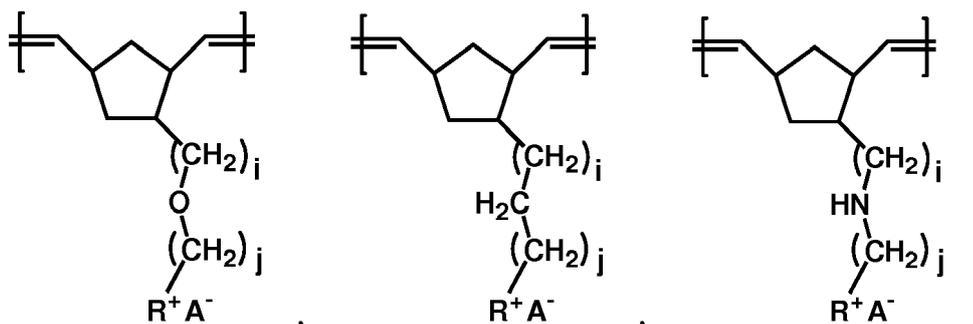
3. The polymer as claimed in claim 1 or 2, wherein R<sup>1</sup> is methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl.

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4. The polymer as claimed in any of claims 1 to 3, wherein R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl.

5. The polymer as claimed in any of claims 1 to 4, wherein the first repeat unit is

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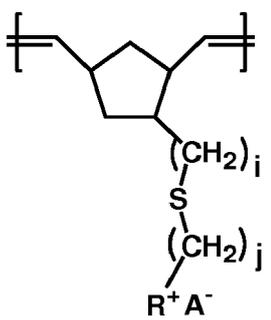


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or

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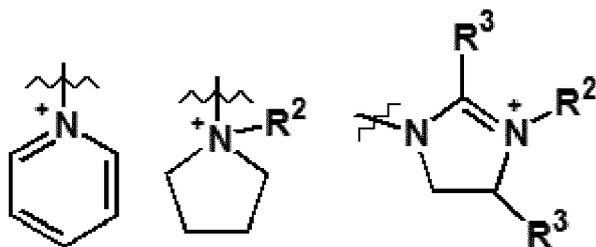
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wherein R<sup>+</sup> is

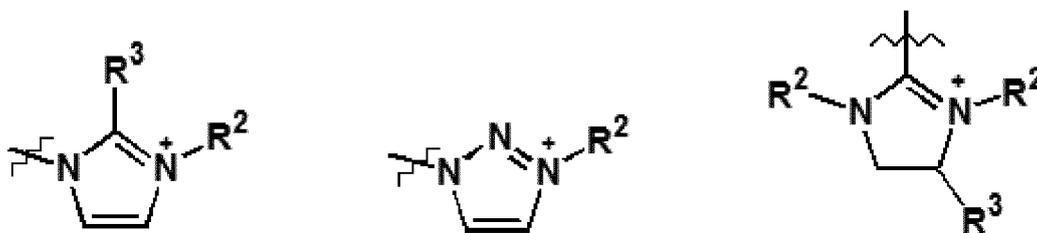
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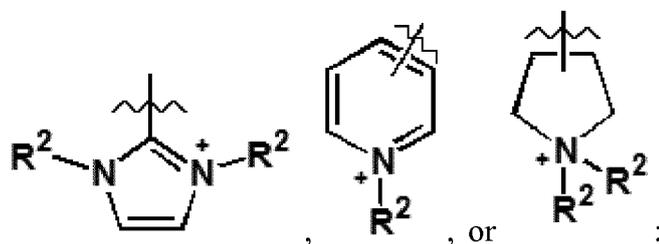
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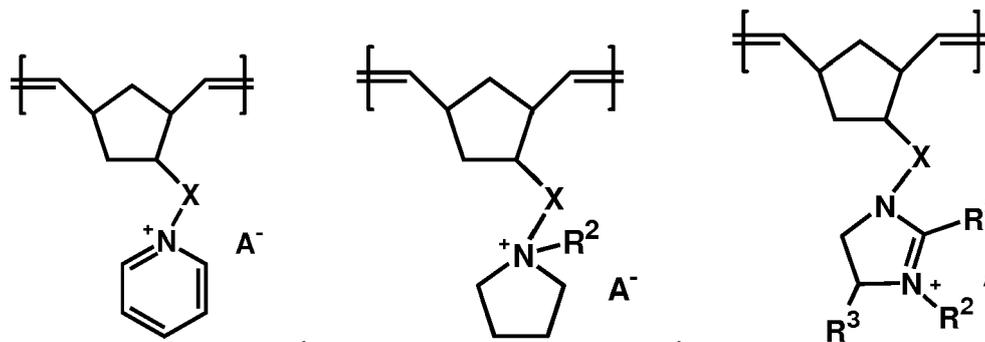


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A<sup>-</sup> is F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; i and j is independently 0, or an integer from 1 to 6; and, R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, or C<sub>1-8</sub> alkyl group.

6. The polymer as claimed in any of claims 1 to 4, wherein the first repeat unit is

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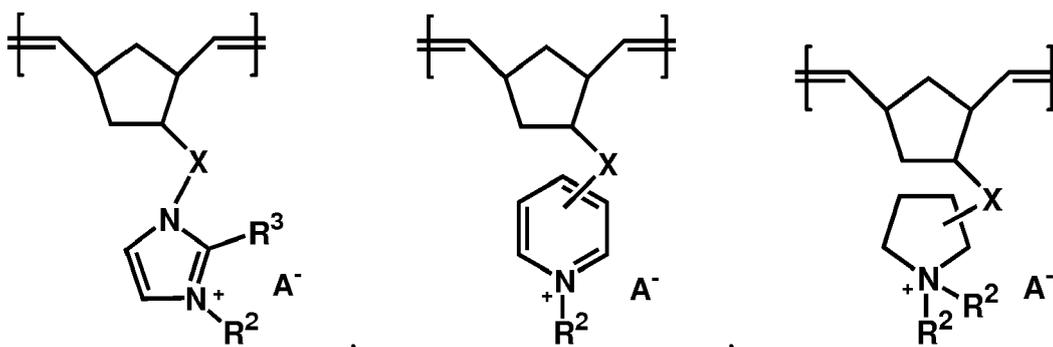


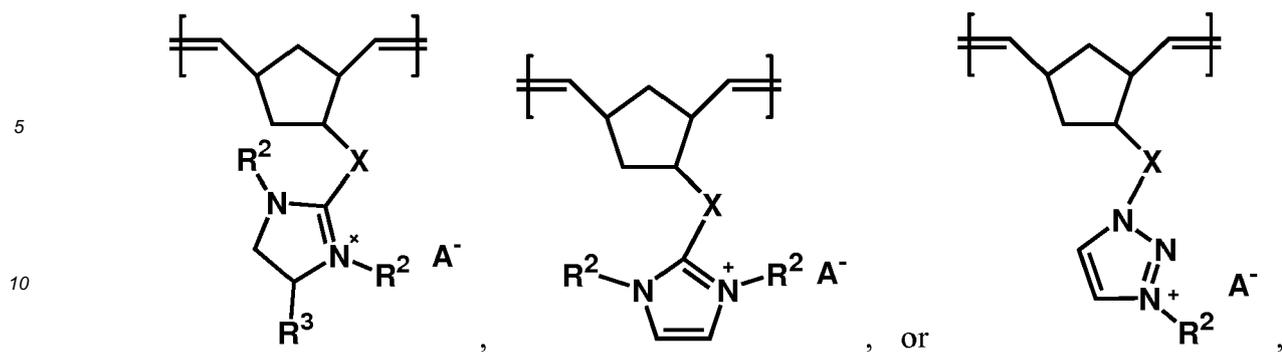
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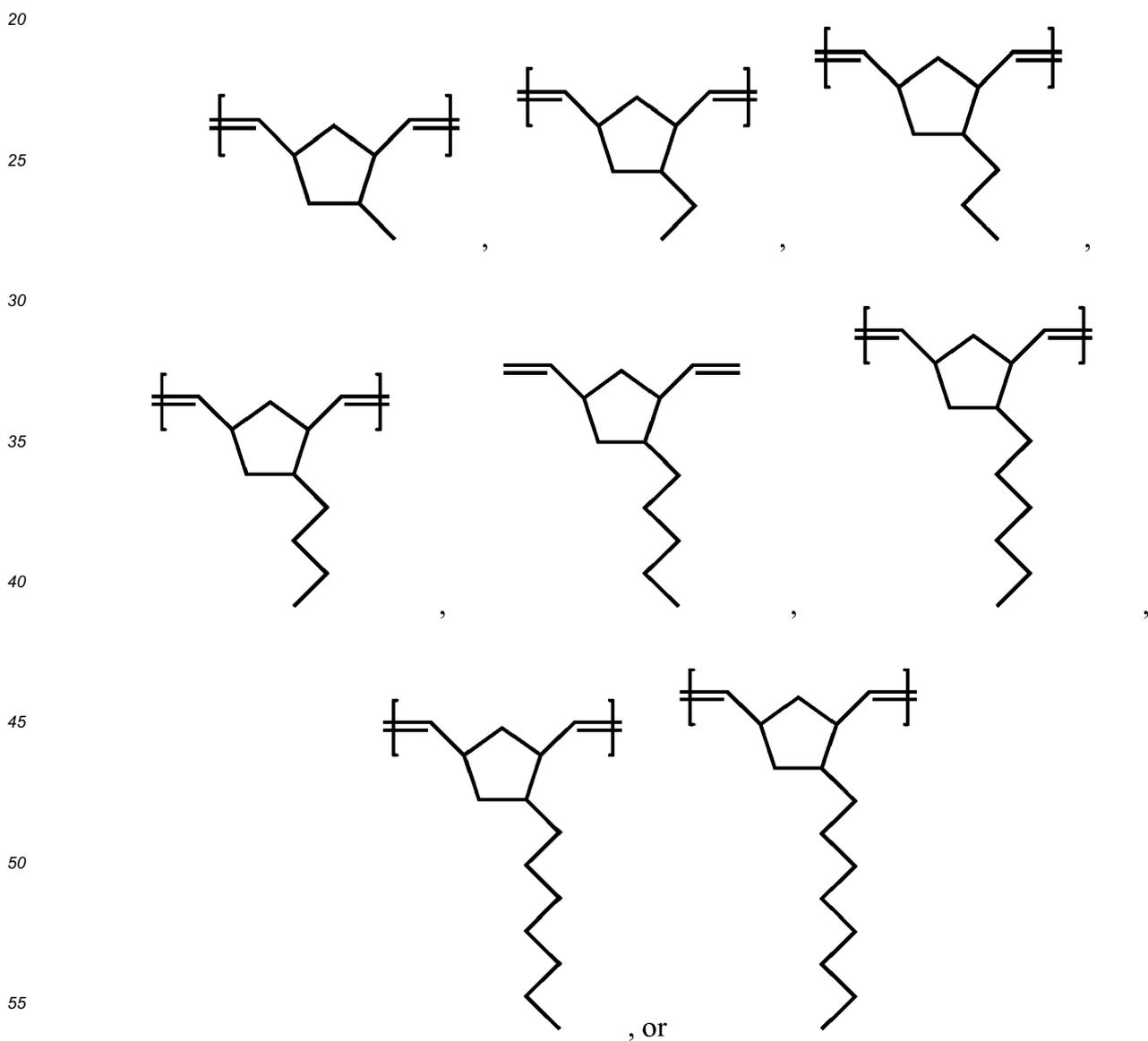
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15 wherein  $A^-$  is  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $OH^-$ ,  $HCO_3^-$ ,  $HSO_4^-$ ,  $SbF_6^-$ ,  $BF_4^-$ ,  $H_2PO_4^-$ ,  $H_2PO_3^-$ , or  $H_2PO_2^-$ ; X is  $\{CH_2\}_iY\{CH_2\}_j$ , i and j is independently 0, or an integer from 1 to 6, Y is  $-O-$ ,  $-S-$ ,  $-CH_2-$ , or  $-NH-$ ; and,  $R^2$  and  $R^3$  are independently hydrogen, or  $C_{1-8}$  alkyl group.

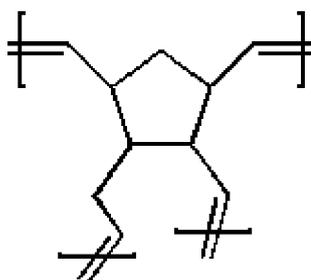
7. The polymer as claimed in any of claims 1 to 6, wherein the second repeat unit is



8. The polymer as claimed in any of claims 1 to 7, wherein the polymer further comprising a third repeat unit, wherein

the third repeat unit is

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9. The polymer as claimed in claim 8, wherein the ratio between the third repeat unit and the sum of the first repeat unit and the second repeat unit is between 0.1:100 and 5:100.

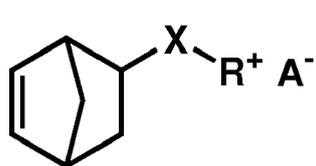
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10. A method for preparing the polymer as claimed in claim 1, comprising:

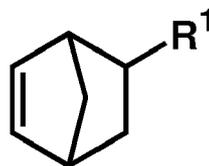
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subjecting a composition to a polymerization, wherein the composition comprises a first monomer having a structure of Formula (I), and a second monomer having a structure of Formula (II)

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Formula (I)

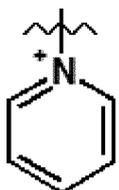


Formula (II)

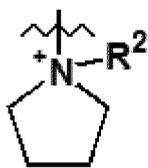
wherein R<sup>+</sup> is

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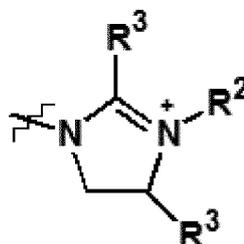
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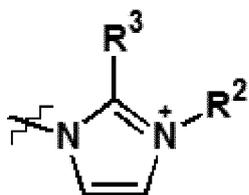
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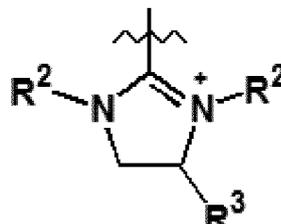
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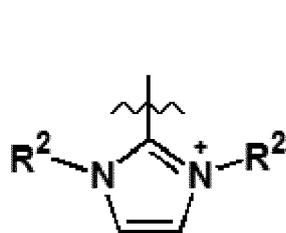
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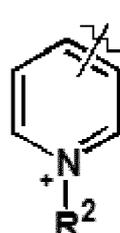
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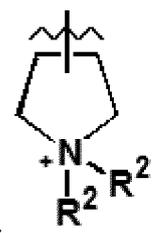


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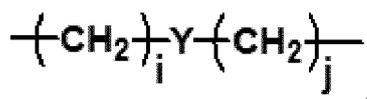
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or



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A<sup>-</sup> is F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, HSO<sub>4</sub><sup>-</sup>, SbF<sub>6</sub><sup>-</sup>, BF<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, H<sub>2</sub>PO<sub>3</sub><sup>-</sup>, or H<sub>2</sub>PO<sub>2</sub><sup>-</sup>; X is



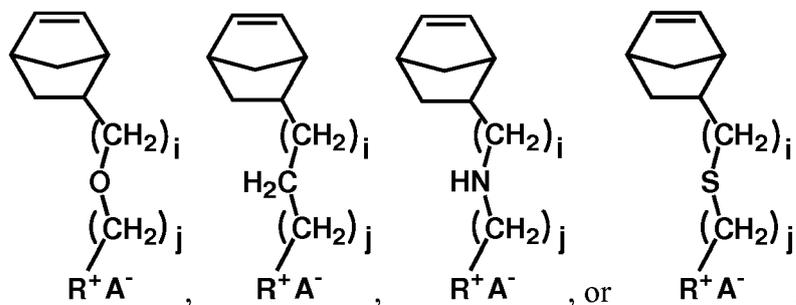
i and j is independently 0, or an integer from 1 to 6, Y is -O-, -S-, -CH<sub>2</sub>-, or -NH-; R<sup>1</sup> is independently C<sub>1-8</sub> alkyl group; and, R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, or C<sub>1-8</sub> alkyl group.

11. The method as claimed in claim 10, wherein the molar ratio between the first monomer and the second monomer is between 1:99 and 99:1.

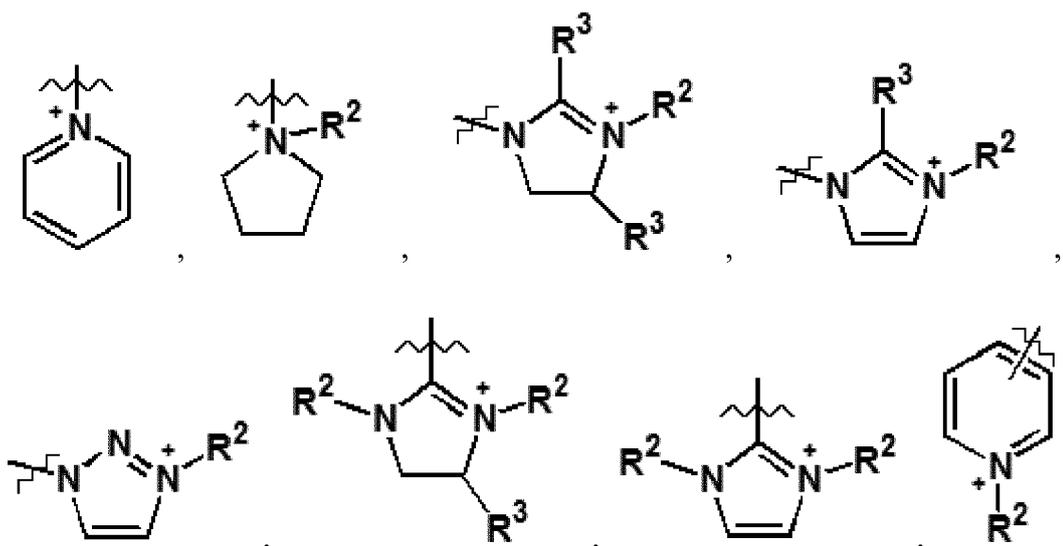
12. The method as claimed in claims 10 or 11, wherein R<sup>1</sup> is methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl.

13. The method as claimed in any of claims 10 to 12, wherein R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, cyclohexyl, cyclopentyl, heptyl, or octyl.

14. The method as claimed in any of claims 10 to 13, wherein the first monomer is

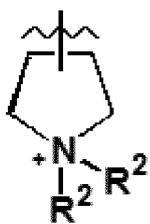


wherein R<sup>+</sup> is



or

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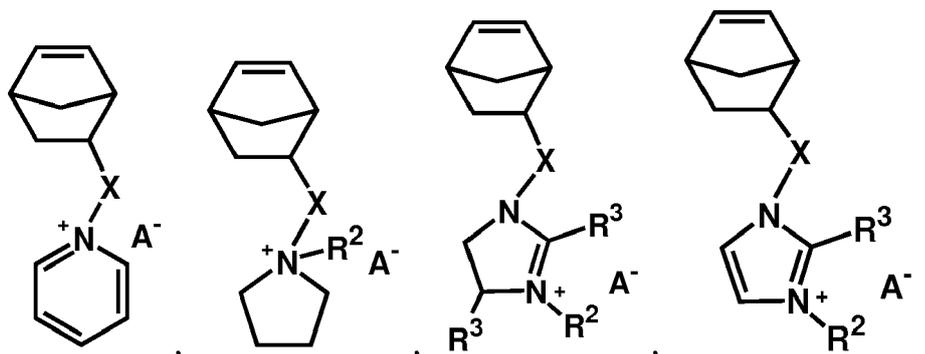
10  $A^-$  is  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $OH^-$ ,  $HCO_3^-$ ,  $HSO_4^-$ ,  $SbF_6^-$ ,  $BF_4^-$ ,  $H_2PO_4^-$ ,  $H_2PO_3^-$ , or  $H_2PO_2^-$ ;  $i$  and  $j$  is independently 0, or an integer from 1 to 6; and,  $R^2$  and  $R^3$  are independently hydrogen, or  $C_{1-8}$  alkyl group.

15. The method as claimed in any of claims 10 to 13, wherein the first monomer is

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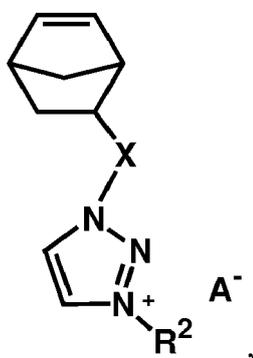
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or

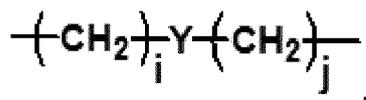
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wherein  $A^-$  is  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $I^-$ ,  $OH^-$ ,  $HCO_3^-$ ,  $HSO_4^-$ ,  $SbF_6^-$ ,  $BF_4^-$ ,  $H_2PO_4^-$ ,  $H_2PO_3^-$ , or  $H_2PO_2^-$ ;  $X$  is



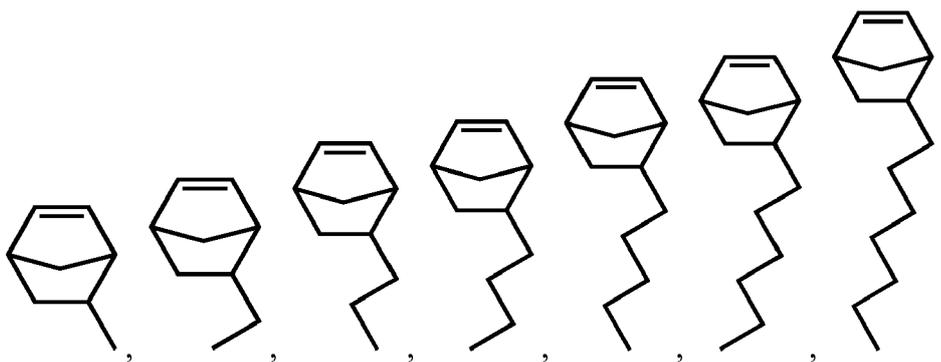
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i and j is independently 0, or an integer from 1 to 6, Y is -O-, -S-, -CH<sub>2</sub>-, or -NH-; and, R<sup>2</sup> and R<sup>3</sup> are independently hydrogen, or C<sub>1-8</sub> alkyl group.

10 **16.** The method as claimed in any of claims 10 to 15, wherein the second monomer is

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or

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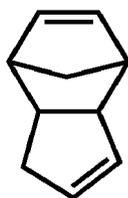
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**17.** The method as claimed in any of claims 10 to 16, wherein the composition further comprises a third monomer, wherein the third monomer is

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**18.** The method as claimed in claim 17, wherein the molar ratio between the third monomer and the sum of the first monomer and the second monomer is between 0.1:100 and 5:100.

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| Place of search<br>Munich  |   | Date of completion of the search<br>13 July 2016   | Examiner<br>Meiners, Christian  |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |   | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |   |

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